

Unattended Deep Space Station Tracking Station Development: Monitor and Control Technology

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The major developments leading to successful demonstration of fully unattended operation of a DSN station (DSS 13) are reviewed. Unattended operation was demonstrated by reliably tracking, commanding, and delivering telemetry from the Pioneer 8 spacecraft. Transfer of automated monitor and control technology to DSN implementation is summarized, along with related accomplishments.

I. Introduction

In 1975, the Deep Space Network began to investigate operating an unattended tracking station as a means of lowering cost, adding to personnel safety, providing improved tracking time, and reducing DSN equipment maintenance. The DSS 13 station was used as the testbed for developing a remotely controlled, unattended station. The unattended operation configuration at DSS 13 included a 26-m antenna, a high-power transmitter, a receiver-exciter, a subcarrier demodulator, a command system, a waveguide switching system, and a data path to JPL (Fig. 1). The project was stretched over several years due to funding constraints and the need to develop complex subsystem transducers.

Several demonstrations were scheduled to validate the design concepts well in advance of final program completion. These demonstrations were carried out as each major subsystem was added to the testbed. Fully unattended receiver capability was demonstrated for 6 months in 1979 to provide controlled lifecycle cost data (Ref. 1). Unattended operation of the high-power transmitter was demonstrated for 2 months in 1981 (Ref. 2). Fully unattended station operation was demonstrated by tracking Pioneer 8 in 1984.

II. Control Architecture

A functional requirements document was developed describing software standards and design. This document set forth distributed control as the system design philosophy. Each major class of equipment (microwave, receiver-exciter, subcarrier demodulator, command, and transmitter) had its own controller, which interfaced to the station controller. Each subsystem controller is capable of operating, diagnosing, and monitoring its assigned subsystem from a local terminal. This philosophy of distributed division of control allowed a viable fallback position for semiautomatic operation of the station if the station controller failed, thereby providing uninterrupted use of DSS 13 for other projects. One or two engineers for each subsystem were responsible for developing software that could configure, operate, and maintain safe operation of their subsystem. An added advantage to this independent design philosophy was that concepts could be tested separately and individual subsystem implementations could be late with little impact on the overall station.

The basic unattended station architecture consists of a remote satellite controller at JPL's NOCC, and a station controller at DSS 13 that communicates with the independent

subsystem controllers (Fig. 2). All controllers use an 8080 CPU-based microprocessor developed and assembled at JPL. The principal monitor and control functions are distributed among the subsystem controllers as described below.

- (1) NOCC controller. The NOCC controller serves as an automatic scheduler, message router, and operator interface. This controller provides an interface to the operator, DSN predicts files, scheduling files, and the DSS 13 station controller. The NOCC controller routes directives for configuration, predicts, command, and operation. It receives and automatically logs all configuration and performance data.
- (2) Station controller. The station controller functions as the supervisory computer, responsible for receiving and transmitting subsystem control directives and for coordination of the overall tracking system. The station controller can be operated from either the NOCC controller or by a local operator. Based on the operational scenarios supplied by the station controller, each subsystem controller performs the detailed tasks required to calibrate, safely operate, and read/write its assigned functions. For example, the station controller has control of the acquisition process after receiving a directive to operate from the NOCC or via local terminal. The station controller continuously monitors the necessary conditions for proper operation. If a subassembly fails, it is possible to maintain the communications channel via the station controller by implementing a prearranged reconfiguration of a backup assembly.
- (3) Antenna controller. The antenna controller monitors the antenna servo and mechanical subsystem and local weather conditions. It controls antenna pointing via high-level operator directives. The antenna controller also contains a separate maintenance program that allows maintenance personnel to fully characterize the electrical and mechanical functions of the antenna during scheduled off-line maintenance (Ref. 3).
- (4) Receiver-exciter controller. The receiver-exciter controller maintains the receiver-exciter configuration and tunes the uplink and downlink signal. Acquisition of the spacecraft downlink is accomplished automatically in a manner similar to the actions performed by a skilled operator.
- (5) Microwave controller. The microwave controller manages and monitors high-power transmitter paths to ensure the safety of personnel and equipment. The controller also monitors and controls the transmitting and receiving signal paths.

- (6) Subcarrier demodulator controller. The subcarrier demodulator controller monitors the performance and controls the configuration to provide automatic acquisition. It provides a graphic output of the correlation meter to the operator for use in manual acquisition when the predicts supplied are not within the demodulator's acquisition bandwidth.
- (7) High-power transmitter controller. The high-power transmitter controller controls and monitors all safety functions, power calibration, and operation of the high-power transmitter subsystem (Ref. 2).
- (8) Traveling wave maser (TWM) and closed-cycle refrigerator (CCR) controller. The TWM/CCR controller provides continuous monitoring of CCR performance data. This data was automatically logged 24 hours a day over a 3-month period and was used to supply engineering with performance numbers previously unavailable because of manpower limitations. This data will be used to characterize CCR performance and eventually to prevent data loss due to unexpected warmup of the TWM (Ref. 4).

III. Pioneer 8 Demonstration and Related Design Tasks

Before a planned tracking demonstration using Pioneer 8 could take place, two new design tasks arose. An improved acquisition detector was required to reach the receiver threshold (Pioneer 8 was 5 dB below the current auto acquisition detector threshold). Also, a multibus version of the DSN command modulator was required because the existing modulator was needed to support operations at Mil 71.

A fast Fourier transform (FFT) automatic acquisition module was designed into the unattended station configuration for the Pioneer 8 demonstration. The FFT module performs a parallel search of the RF spectrum for the desired signal and estimates the difference in frequency between the spacecraft signal and the frequency to which the receiver is tuned. The spacecraft downlink signal is nearly sinusoidal, and based on previous experience and theory of optimum receiver sinusoidal signals of unknown phase (Ref. 5), it was decided that the best approach would be to use power spectrum analysis techniques. The idea was to produce the spectrum, scan it for peaks, and estimate the difference between the frequency of the peak and the frequency to which the receiver was currently tuned. The implementation is shown in Fig. 3. The 10-MHz IF signal plus noise is mixed with a 10-MHz reference signal. The two quadrature components produced are then digitized and processed through a complex-to-complex FFT routine. The resulting Fourier transform is

squared to produce a power spectrum, averaged to statistically reduce the variance of the signal, and inspected by the computer for significant spectral peaks. The FFT acquisition module runs continuously and asynchronously without control inputs. The spectrum estimated SNR and the estimated tuning correction are passed to the receiver controller, where they are used to automatically retune to the spacecraft frequency and to acquire the signal.

The command modulator assembly (CMA) was designed to fit on a standard multibus board and reside in the station controller chassis (Fig. 4). The CMA was tailored for the Pioneer 8 demonstration, but was designed so that it could be easily modified to support the tracking of other spacecraft. The CMA provides frequency shift key (FSK) modulation synchronous with the subcarrier. It also provides configuration verification and transmitted bit confirmation. If any data is not verified, the command sequence is aborted, the operator is notified that the command was not sent, and the probable cause of failure is displayed.

By 1984, DSS 13 was successfully operating in the unattended station configuration — routinely tracking several spacecraft downlinks and remotely operating the high-power transmitter on a daily basis. The next logical step was to take on a full tracking assignment, including uplink tuning and command of a spacecraft. When the Pioneer 8 spacecraft became available, a set of demonstration objectives was defined in order to evaluate whether the DSS 13 unattended tracking configuration could safely and reliably perform assigned spacecraft tracking missions. The evaluation was based on tracking Pioneer 8 twice a week and measuring the station's ability to acquire the spacecraft signal at the scheduled time, tune the uplink, send and verify commands, return the spacecraft to its previous state, and collect telemetry data at JPL. The data was sent to the Project Office at NASA/Ames for validation. If station personnel were required in any

capacity, the track pass was deemed a failure. The Pioneer 8 demonstration took place for a 12-month period and resulted in 87 tracks. The results are shown in Fig. 5. As can be seen, the success and reliability improved over time. At no time after successful uplink acquisition did a command fail to be sent. Also, the spacecraft was never left in a state different than what was planned at the start of the track.

IV. Accomplishments

- (1) The unattended station development effort has provided the DSN with new options for automated and remotely controlled tracking stations.
- (2) High-level computer languages were adopted, tested, and transferred to implementation.
- (3) The high-power transmitter and waveguide switch subsystems were transferred to DSN implementation with little or no change.
- (4) New tools were developed and tested that increased productivity in the development and troubleshooting of complex real-time control systems that have distributed processors embedded in the control feedback.
- (5) New digitally programmed oscillators were developed and transferred directly to operations in time to solve tuning problems that occurred with the Voyager spacecraft (POCA, DCO).
- (6) The philosophy of containing all safety decisions at the subsystem level and out of the hands of the operator eliminated the threat of injury to personnel and equipment during tracking.
- (7) Not one piece of equipment was ever damaged due to the automation, and equipment failure rates went down because handling of equipment was reduced.

References

1. "Deep Space Station (DSS 13) Automation Demonstration," *TDA Progress Report 42-57*, pp. 103-119, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1980.
2. "High-Power Transmitter Automation," *TDA Progress Report 42-57*, pp. 71-81, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1980.
3. "DSS 13 Microprocessor Antenna Controller," *TDA Progress Report 42-77*, pp. 64-74, Jet Propulsion Laboratory, Pasadena, Calif., May 15, 1984.
4. "Traveling-Wave Maser, Closed Cycle Refrigerator Automation," *TDA Progress Report 42-65*, pp. 99-103, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1981.
5. Viterbi, A. J., *Principles of Coherent Communication*, McGraw Hill, NY, NY, 1966.

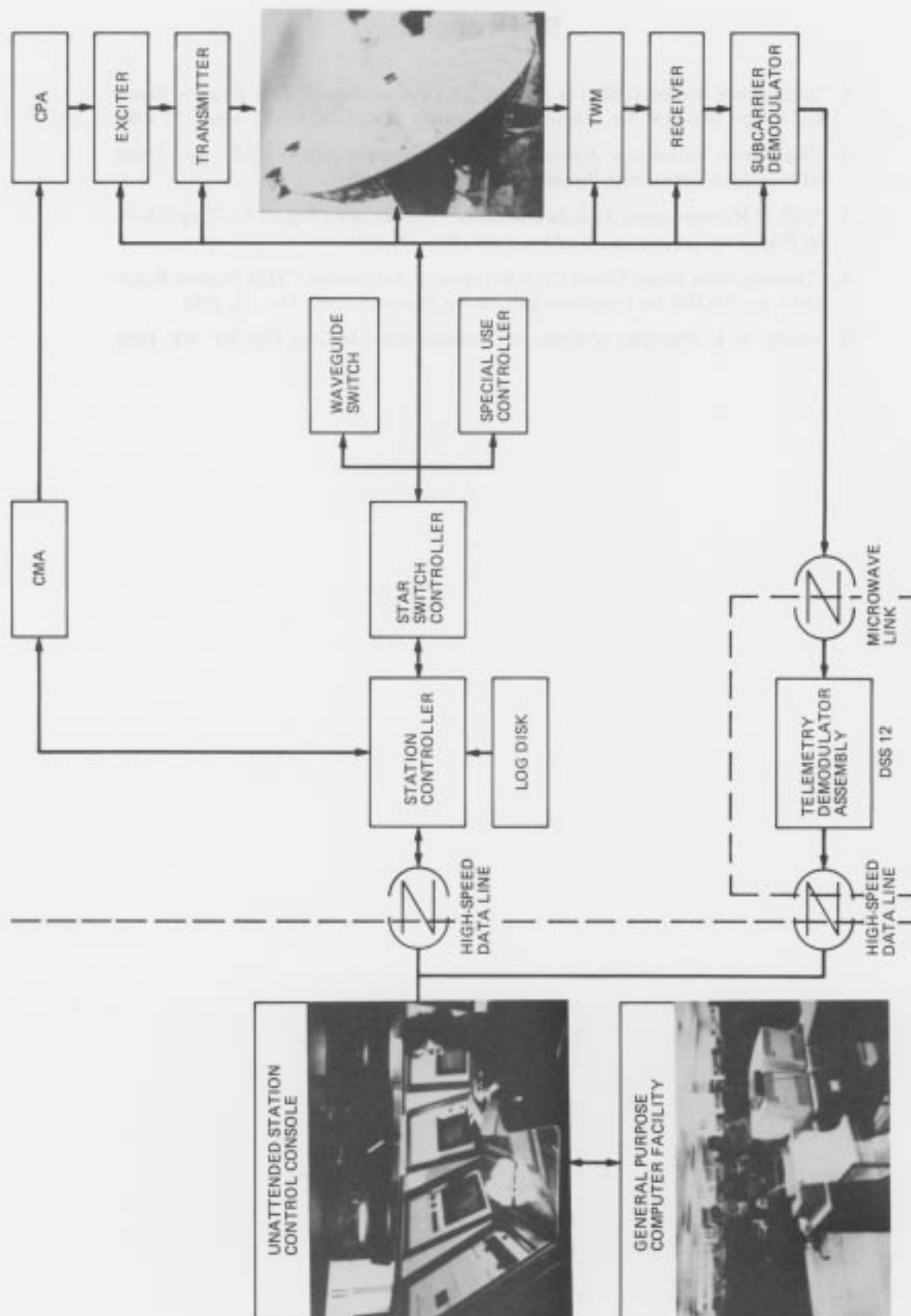


Fig. 1. DSS 13 unattended station system block diagram

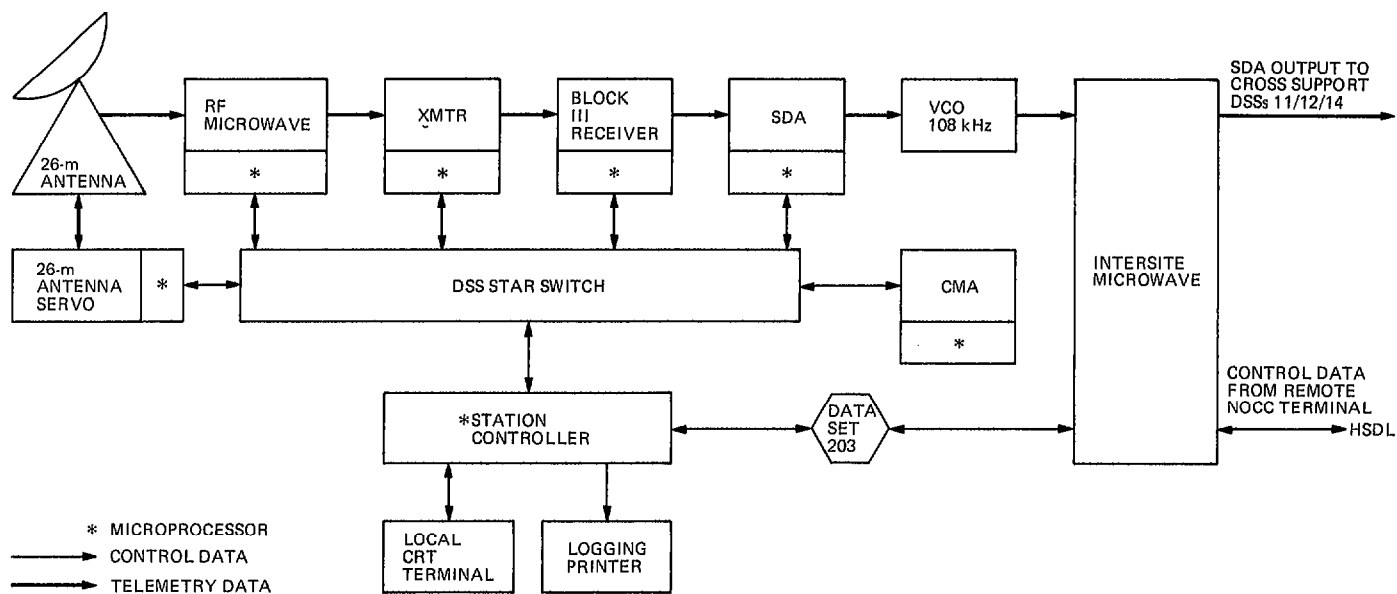


Fig. 2. DSS 13 unattended station functional block diagram

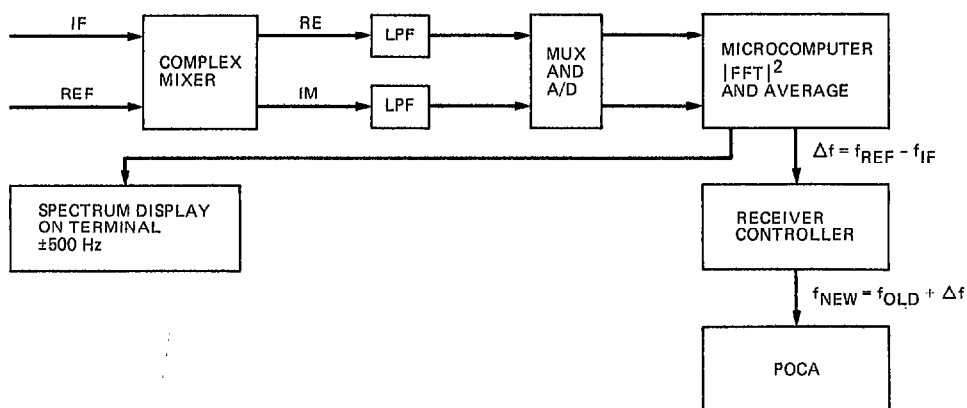


Fig. 3. FFT acquisition aid functional block diagram

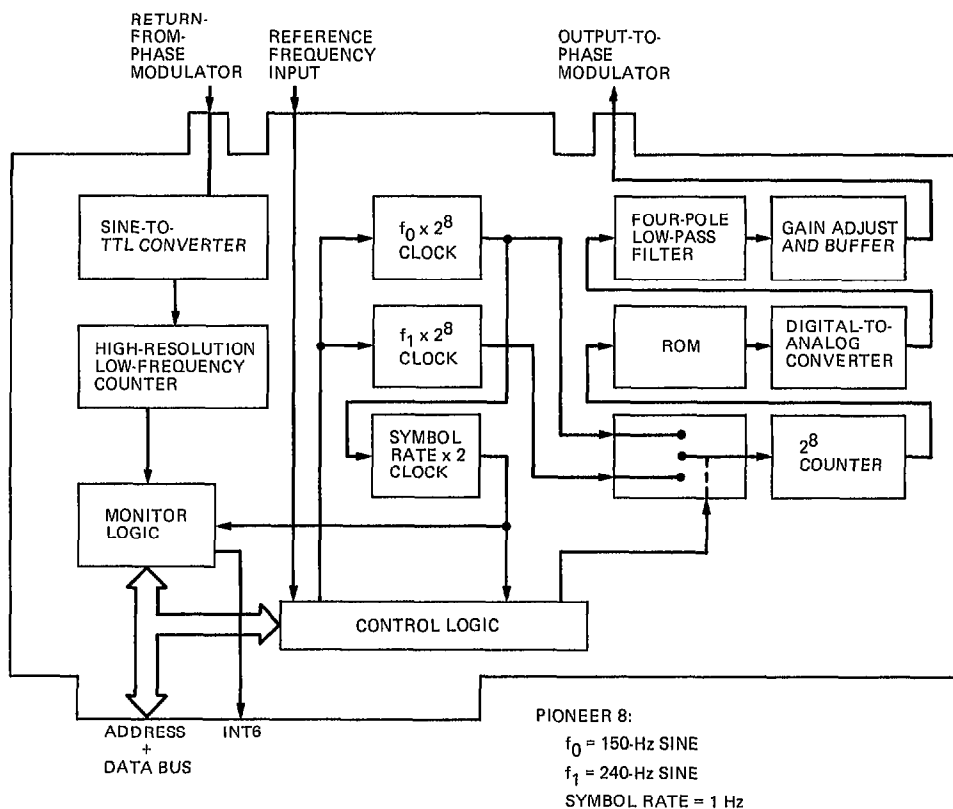


Fig. 4. Command modulator assembly functional block diagram

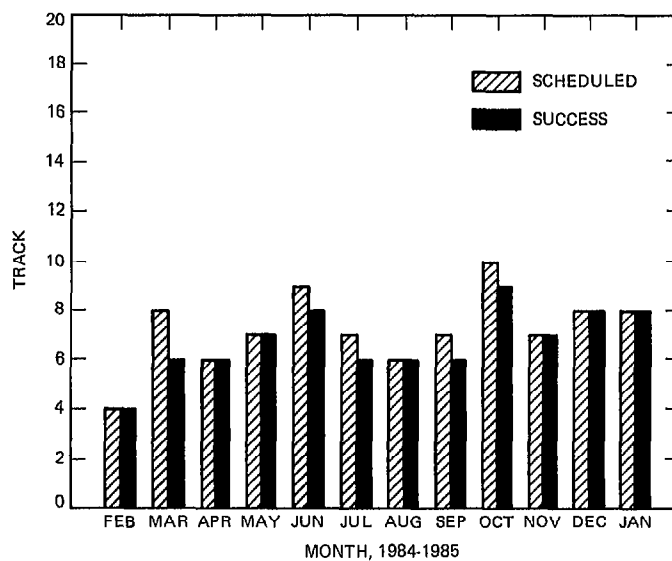


Fig. 5. DSS 13 Pioneer 8 tracking demonstration schedule and success ratio